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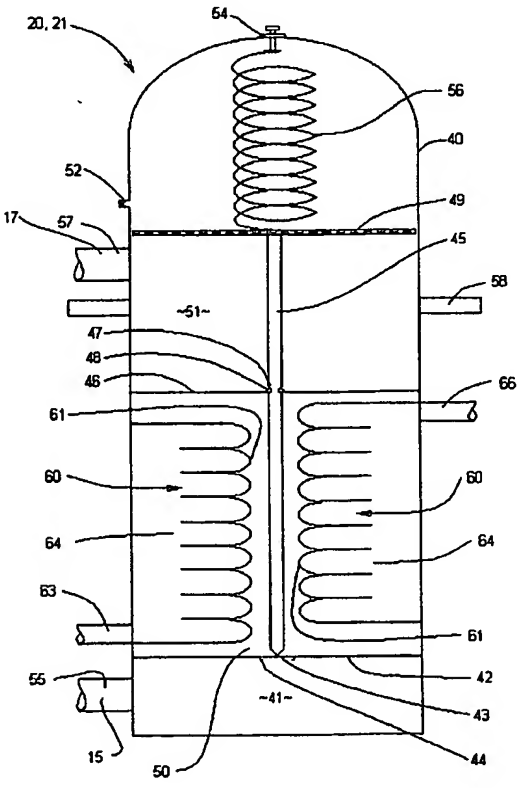
(54) Title: LIQUID FUEL VAPOURISATION APPARATUS FOR FUEL INJECTED INTERNAL COMBUSTION ENGINES



(57) Abstract: Liquid fuel vapourisation apparatus (20) including: first pressure reduction means (43, 44) for receiving liquid fuel and reducing its pressure to a first controlled pressure to vapourise at least some of the fuel; a vapouriser (50) in fluid communication with the first pressure reduction means (43, 44) for receiving the partly vapourised fuel and vapourising the remainder of the liquid fuel to provide a gaseous fuel; a second pressure reduction means (47, 48) in fluid communication with the vapouriser (50) for receiving the gaseous fuel and reducing its pressure thereof to a second controlled pressure for delivery (17) to one or more of the fuel injectors of an internal combustion engine. The first and second pressure reduction means (43, 44, 47, 48) are either operatively interposed between the throttle body and the intake manifold of the engine or operatively incorporated into a throttle body.

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"LIQUID FUEL VAPOURISATION APPARATUS FOR FUEL INJECTED INTERNAL COMBUSTION ENGINES"

TECHNICAL FIELD

THIS INVENTION relates to liquid fuel vapourisation apparatus for spark ignition fuel injected internal combustion engines. The invention also has application to carbureted internal combustion engines which can be converted to fuel injection internal combustion engines.

BACKGROUND ART

Internal combustion engines designed to run on petrol (sometimes called gasoline) are often converted to run on liquid petroleum gas (LPG). More recently, automotive manufacturers have provided vehicles having LPG instead of petrol as the fuel source, avoiding the need for conversion. There are many forms of conversion available, however, the method of carburetion or fuel injection arising from the conversion may result in some drawbacks, such as, for example, difficulty in starting hot engines. While it has been found that using a fuel in the gaseous phase may have benefits, running LPG fuel as a vapour from the LPG tank creates a heat sink in the tank due to the energy required to evaporate the LPG fuel. On the other hand, petrol is liquid at ambient conditions, and vapourisation of the liquid fuel requires heat input, such as from the engine coolant. There have been proposals for dual fuel internal combustion engines, however, such proposals usually require the LPG to be delivered to the combustion chamber as a liquid under much the same phase conditions as liquid fuels, thus foregoing the benefits of having a vapour and air mix in the combustion chamber prior to ignition.

Sometimes, engines with liquid fuel injection systems converted to run on LPG merely inject gas into the throat of the air intake manifold and rely on natural or forced aspiration to control fuel supply, bypassing the fuel injectors, foregoing the advantages of precise fuel delivery time and quantity offered by fuel injection.

It has also been suggested that the fuels used in internal combustion engines are not necessarily ideal in that combustion occurs relatively slowly due to the fuel consisting of a range of molecular weights of hydrocarbon. The lighter fractions ignite before heavier fractions which sometimes remain unburnt and may contribute to photochemical smog unless catalytically oxidised prior to emission from the tail pipe of the vehicle. A narrower range of molecular weights in the constituents of the fuel may lead to better efficiency since the combustion will be more predominantly percussive than would be the case for fuel having a wider range of molecular weights in its constituents.

The present invention aims to provide vapourised liquid fuel injection apparatus for internal combustion engines which alleviates one or more of the aforementioned problems, or at least to provide a useful alternative to present fuel systems for internal combustion engines. Other aims and advantages may become apparent from the following description.

SUMMARY OF THE INVENTION

With the foregoing in view, this invention in one aspect resides broadly in liquid fuel vapourisation apparatus for a fuel injected internal combustion engine having a throttle body and an intake manifold, the apparatus including:

first pressure reduction means for receiving liquid fuel and reducing the pressure of the liquid fuel to a first controlled pressure, at which at least some of the fuel may be vapourised;

a vapouriser in fluid communication with the first pressure reduction means for receiving the partly vapourised fuel therefrom and vapourising the remainder of the liquid fuel to provide a gaseous fuel at the first controlled pressure;

second pressure reduction means in fluid communication with the vapouriser for receiving the gaseous fuel and reducing the pressure thereof to a second controlled pressure for delivery to one or more of the fuel injectors of the internal combustion engine to which the apparatus is fitted.

The first and second pressure reduction means may be adapted to be operatively interposed between the throttle body and the intake manifold of the engine, or alternatively, the first and

second pressure reduction means being operatively incorporated into a throttle body which in turn is adapted to be operatively connected to the intake manifold of the engine. It will be appreciated that the internal combustion engine may have been converted from an a carbureted combustion engine to a fuel injected internal combustion engine.

In another aspect the invention resides broadly in an internal combustion engine having an intake manifold and a throttle body in fluid communication with the intake manifold, characterised in that liquid fuel vapourisation apparatus as previously described is operatively connected between the throttle body and the intake manifold. The first and second pressure reduction means described above may be formed as a two-stage regulator.

Preferably, catalytic cracking means is operatively connected in the fluid flow path between the second pressure reduction means and the intake manifold for thermal catalytic reduction of the gaseous fuel received therefrom to produce a cracked fuel having constituents of substantially lower molecular weight.

Preferably, the second pressure reduction means is operable to regulate the pressure of the fuel in the vapour state so that the ratio of the absolute gas supply pressure to the injectors to the absolute manifold pressure is 1.85 or greater. It is believed that this ratio will ensure that the gas flowing through the injectors reaches sonic velocity, thereby causing the mass flow rate to be close to proportionate to the supply pressure. Using supply pressure as an analogue for mass flow rate, under sonic conditions, an accurate quantity of fuel may be delivered by accurately controlling supply pressure of the fuel. It will be appreciated that for supercharged or turbocharged engines, a higher pressure will be required.

Pressure regulators typically reduce the pressure of LPG drawn from the top of the tank as a vapour using a needle and seat together with a spring loaded diaphragm to regulate the pressure relative to the vent port. In the present invention, it is preferred that the first pressure reduction means comprises

a first needle and seat type valve through which liquid fuel may enter and a second needle and seat type valve comprising the second pressure reduction means, the ratio of the effective cross sectional area of the first needle and seat to that of the second needle and seat being selected to reflect the expected increase in volume accompanying the phase change. In a preferred form the ratio is about 1:270 for LPG.

In a preferred form, the first and second needles are opertively connected by a common shaft to a spring loaded diaphragm. More preferably, the first and second needles are formed in the common shaft. The side of the diaphragm remote from the needles may be either vented to atmosphere or arranged for fluid connection with the intake manifold making the output pressure of the vapouriser apparatus relative to either atmospheric pressure or to manifold pressure respectively. In the case of supercharged or turbocharged engines, the vent is provided with a fluid connection such that the extra pressure supplied to the engine is also transmitted to the remote side of the diaphragm. In the case of centrifugal superchargers, the spring may be selected to exhibit non-linear compression characteristics to provide the pressure regulation which may be necessary for such engines.

Where a catalytic cracking means is provided, it is preferred that the vaporisation means heats the gaseous fuel to a temperature of between 190° and 235°C for unleaded standard grade petrol, and that a quantity of water is provided to vaporise and provide a source of hydrogen and/or oxygen in reactive form for catalytic combination with some components of the petrol and produce lower molecular weight hydrocarbons and/or alcohols. A thermal catalyst is believed to be suitable for this purpose, and may be selected for example, from the zeolites, to catalytically crack the fuel from the liquid fuel source to a desired cracked fuel composition consisting of components of a narrow range of molecular weights which will produce a more percussive type combustion in the combustion chamber of the engine than the liquid fuel prior to catalytic cracking.

The injector or injectors may be fitted to a plate between the throttle body and the manifold. In such an arrangement, it is preferred that the plate also supports the two-stage regulator, filter and a shut-off solenoid valve such that all of the desired components are in a unitary assembly. It will be seen that this arrangement may have the advantage of reducing complexity and cost. Alternatively, a separate injector may be used for each cylinder or bank of cylinders and operatively connected into the manifold at the appropriate position. This approach may be necessary in the case of engines which have their idle air control motor/valve located between banks of cylinders to equalise gas distribution to all cylinders.

It is believed that in addition to pressurised, liquified gaseous fuels, the apparatus of present invention may be used for fuels which are normally liquid at standard atmospheric conditions, such as petrol, diesel oil, and low molecular weight alcohols, in which case the fuel may be stored in a non-pressurised tank and pressurised by a pump before being vapourised and injected. It will be appreciated that non-fractionating fuels would be suitable for use with the liquid fuel vapouriser apparatus of the present invention. If the engine is to be supplied with more than one type of fuel, a separate vapouriser would be necessary, each vapouriser having the ratio of the respective effective cross sectional areas of the first and second needle seats selected to reflect the expected volume increase in the change of phase for each particular fuel to be used.

The vapouriser may also include means for enhancing the phase change from liquid to vapour, such as a catalyst, or such like, or what is sometimes known in the art as an ebulator. The vapouriser includes a housing to enclose the vapour and liquid and house the ebulator.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the invention may be more readily understood and put into practical effect, reference will now be made to the accompanying drawings which illustrate a preferred embodiment of the invention, and wherein:

Fig. 1 is a schematic diagram of a fuel supply system for an internal combustion engine incorporating liquid fuel vapourisation apparatus according to the invention and, in dotted outline, a combined vapourisation apparatus and thermal catalytic cracker, and in which the engine has four vapour fuel injectors;

Fig. 2 is a schematic diagram showing the location of the liquid fuel vapourisation apparatus between a throttle body and an intake manifold for an internal combustion engine similar to that of Fig. 1, but having two vapour fuel injectors; and

Fig. 3 is a diagrammatic sectional view of a dual seat valve assembly for the liquid fuel vapourisation apparatus of Figs. 1 and 2.

The fuel supply system 10 illustrated in Fig. 1 includes a fuel tank for liquid fuel (pressurised LPG) 13, for supplying fuel in liquid form from the tank through a fuel tank valve 12 to a liquid fuel line 15. Alternatively, or in addition thereto, a fuel tank for petrol (shown in dotted outline at 11) is provided with a fluid connection to a fuel pump 14 which in turn has its output in fluid connection to the liquid fuel line 15. A fuel pump would be necessary for LPG if the ambient temperature is insufficient for the vapour pressure to be above the required regulated pressure (after allowing for pressure losses through the tubing, valves etc.) for the particular composition of the LPG.

In the case of the LPG fuel tank, the liquid fuel line is in fluid communication with the liquid fuel vapourisation apparatus 20, which in turn is in fluid communication with a vapour fuel line 17 feeding four fuel injectors shown typically at 25. In the case of the petrol fuel tank, the liquid fuel line is in fluid communication with the combined vaporisation apparatus and thermal catalytic cracker 21, which in turn is in fluid communication with the vapour fuel line 17 shown in dotted outline, and which also feeds the fuel injectors described above.

The fuel injectors are controlled by four respective injector control cables shown typically at 26 which are in

electrical connection with an electronic control unit 28. In use, the liquid fuel is fed through the fuel tank valve and then through the liquid fuel line to the liquid fuel vapourisation apparatus by the pump or under pressure of the liquid and gas in the fuel tank. The liquid fuel is vapourised in the liquid fuel vapourisation apparatus and fed into the vapour fuel line, and thence to the individual injectors which inject the vapourised fuel into the respective combustion chambers of the engine under control of the electronic control unit. In the case of the petrol fuel, the gas phase fuel emerging from the second stage of the pressure reduction is heated and passed over zeolite catalyst to crack the heavier fractions to lighter molecular weight components. Optionally, water may be added from a water tank 18 to provide reactive hydrogen and/or hydroxyl groups to assist the cracking process.

Referring to Fig. 2, the liquid fuel vapourisation apparatus 20 is mounted on a plate 33 having therethrough a throat 34, and which is inserted between the throttle body 32 and the manifold 31. Two fuel injectors 25 are also mounted to the plate for injecting vapourised fuel into the manifold 31 for transport to the combustion chambers of the engine (not shown), the gas from the injectors being injected through respective vapour nozzles 35 in the throat of the plate.

The liquid fuel vapourisation apparatus 20 illustrated in Fig. 3 has a housing 40 with a fuel entry port 55 to which the liquid fuel line 15 is connected, and a vapour fuel outlet port 57 to which the vapour fuel line 17 is connected. A first seat plate 42 extends across the housing, and has an aperture therein forming a first seat 44. The first seat plate and part of the housing define a liquid intake chamber 41 and the liquid fuel line leads into the liquid intake chamber to substantially fill the liquid intake chamber with liquid fuel. A first needle 43 on the distal end of a needle shaft 45 extending substantially axially at least part way through the vapouriser housing is sealingly enagagable with the first seat. A second seat plate 46 extends across the housing at right angles to the housing axis to form a vapourisation chamber 50 intermediate the first and

second seat plates. The second seat plate, in a similar fashion to the first seat plate, has an aperture therethrough forming a second seat 48 into which a second needle 47 is sealably engagable. The first needle and second needle are integrally formed on the needle shaft and extend from a diaphragm 49 which is biassed to close the first and second needles against the first and second needle seats by a spring 56 interposed between the diaphragm and the top of the housing. Also, a vent port 52 is provided in the housing on the other side of the diaphragm from the needle shaft. A vapour chamber 51 is formed between the diaphragm and the second seat plate.

Additionally, to vapourise the fuel in the vapourisation chamber, engine coolant is introduced through a coolant feed port 63 into a coolant chamber 64 which has a convoluted coolant chamber wall 61 dividing the coolant chamber from the vapourisation chamber. Engine coolant introduced through the coolant feed port is returned to the engine cooling system by way of a coolant return port 66. The compression of the spring 56 may be adjusted by an adjusting screw 54 thereby adjusting the biassing force on the first and second needles. The liquid fuel vapourisation apparatus may be secured at a desired location by an annular mounting flange 58 extending radially outward from the vapouriser housing.

In use, liquid fuel pumped or led through the liquid fuel line is fed into the liquid intake chamber, and flow of the liquid from the liquid intake chamber is controlled by the biassing force applied by the spring to the first needle against the first seat. The liquid which passes through the first needle and seat is vapourised in the vapourisation chamber by virtue of both the pressure reduction and the transfer of heat from the engine coolant being re-circulated through the coolant chamber through the coolant chamber walls. If desired, the vapourisation chamber may be packed with contact material to enhance the change of phase from liquid to vapour. The flow of vapour from the vapourisation chamber to the vapour chamber is controlled by the second needle and seat, both the first and second needles and seats being movable axially by action of the pressure of the

liquid and gas on the first and second needles respectively acting against the compensating biassing force of the spring, the biassing force of which is adjustable by virtue of the adjusting screw. The gas pressure in the vapour chamber is equilibrated either to atmosphere through the vent port or to the manifold pressure. The vapour chamber may also be packed with thermal cracking catalyst and a water or steam inlet port to facilitate the catalytic cracking of heavier fractions in the fuel.

In a preferred form, the plate is cast as a body having flow passages provided for connecting injectors, the vapouriser apparatus, fuel filters, shut off solenoids and such other components as desired or required by threaded engagement therewith so that the plate and all of the components can be conveniently interposed between the throttle body and the manifold.

Where the engine is converted from a petrol fuel injection to a vapour fuel injection in accordance with the invention, the vapour injectors are used instead of the petrol injectors of the engine, the preferred vapour injector being a fast response solenoid valve of the type disclosed in United States Patent No. 4,610,267 to Neils J. Beck, Edward T. Gilbert, William E. Weseloh and Kenneth Rudolf.

The existing electronic control unit of the petrol injection engine is used to control the vapour injectors used with the vapouriser apparatus of the present invention which inject the vapour directly into the throat of the intake manifold so that a mixture very close to the stoichiometric ratio of fuel and air is delivered to each combustion chamber in turn under the control of the electronic control unit receiving its signals from sensors typically provided in operative association with the engine. For installation of the liquid fuel vapourisation apparatus in a non-fuel injected engine, vapour fuel injectors may be substituted for liquid fuel injectors from a fuel injection conversion kit, and the electronic control unit of the fuel injection conversion kit can be used to control the vapour fuel injectors fed with the vapourised fuel from the liquid fuel vapourisation apparatus of the present invention.

Although the invention has been described with reference to one or more specific examples, it will be appreciated by persons skilled in the art that the invention may be embodied in other forms within the broad scope and ambit of the invention as defined by the following claims.

CLAIMS

1. Liquid fuel vapourisation apparatus for a fuel injected internal combustion engine having a throttle body and an intake manifold, the apparatus including:

first pressure reduction means for receiving liquid fuel and reducing the pressure of the liquid fuel to a first controlled pressure, at which at least some of the fuel may be vapourised;

a vapouriser in fluid communication with the first pressure reduction means for receiving the partly vapourised fuel therefrom and vapourising the remainder of the liquid fuel to provide a gaseous fuel at the first controlled pressure;

second pressure reduction means in fluid communication with the vapouriser for receiving the gaseous fuel and reducing the pressure thereof to a second controlled pressure for delivery to one or more of the fuel injectors of the internal combustion engine to which the apparatus is fitted.

2. Liquid fuel vapourisation apparatus according to Claim 1, wherein the first and second pressure reduction means are operatively interposed between the throttle body and the intake manifold of the engine.

3. Liquid fuel vapourisation apparatus according to Claim 1, wherein the first and second pressure reduction means are operatively incorporated into a throttle body which in turn is adapted to be operatively connected to the intake manifold of the engine.

4. Liquid fuel vaporisation apparatus according to any one of the preceding claims, and including catalytic cracking means in operative connection with the second pressure reduction means for thermal catalytic reduction of the molecular weight of the gaseous fuel received therefrom to produce a cracked fuel having constituents of substantially uniform molecular weight, the catalytic cracking means being operatively connected to the intake manifold of the engine.

5. Liquid fuel vaporisation apparatus according to any one of the preceding claims, wherein the second pressure reduction means is operable to regulate the pressure of the fuel in the vapour state so that the ratio of the absolute gas supply pressure to the injectors to the absolute manifold pressure is 1.85 or greater.

6. Liquid fuel vaporisation apparatus according to Claim 5, wherein the ratio is selected to ensure that the gas flowing through the injectors reaches sonic velocity, thereby causing the mass flow rate to be close to proportionate to the supply pressure.

7. Liquid fuel vaporisation apparatus according to Claim 5 or Claim 6, wherein the ratio is increased as required for supercharged or turbocharged engines.

8. Liquid fuel vaporisation apparatus according to any one of the preceding claims, wherein the first pressure reduction means comprises a first needle and seat type valve through which liquid fuel may enter and the second pressure reduction means comprises a second needle and seat type valve, the ratio of the effective cross sectional area of the first needle and seat to that of the second needle and seat being selected to reflect the expected increase in volume accompanying the phase change.

9. Liquid fuel vaporisation apparatus according to Claim 8, wherein the first and second needles are opertively connected by a common shaft to a spring loaded diaphragm.

10. Liquid fuel vaporisation apparatus according to Claim 8, wherein the first and second needles are formed in the common shaft.

11. Liquid fuel vaporisation apparatus according to any one of Claims 8 to 10, wherein the liquid fuel vapourisation apparatus includes a housing and a diaphragm forming a chamber within the

housing with a spring interposed between a portion of the housing and the diaphragm remote from the needles whereby vapourised fuel may be vented to atmosphere from the chamber.

12. Liquid fuel vaporisation apparatus according to Claim 11, wherein the side of the diaphragm remote from the needles is arranged for fluid connection with the intake manifold.

13. Liquid fuel vaporisation apparatus according to any one of Claims 8 to 10, wherein, in the case of supercharged or turbocharged engines, the vent is provided with a fluid connection such that the extra pressure supplied to the engine is also transmitted to the remote side of the diaphragm.

14. Liquid fuel vaporisation apparatus according to any one of the preceding claims, wherein the injector or injectors are fitted to a plate between the throttle body and the manifold, the plate supporting the vapouriser and the first and second pressure reduction means in the form of a two-stage regulator, as well as supporting a filter and a shut-off solenoid valve such that all of the desired components are in a unitary assembly.

15. Liquid fuel vaporisation apparatus according to any one of the preceding claims, and adapted for use with pressurised, liquified gaseous fuels.

16. Liquid fuel vaporisation apparatus according to any one of Claims 1 to 14, and adapted for use with fuels which are normally liquid at standard atmospheric conditions, such as petrol, diesel oil, and low molecular weight alcohols, and wherein the fuel is stored in a non-pressurised tank and pressurised by a pump before being vapourised and injected.

17. Liquid fuel vaporisation apparatus according to any one of Claims 1 to 14, and adapted for use with more than one type of fuel, and having a separate vapouriser for each fuel, each vapouriser having the ratio of the respective effective cross

sectional areas of the first and second needle seats selected to reflect the expected volume increase in the change of phase for each particular fuel.

18. Liquid fuel vaporisation apparatus according to any one of the preceding claims, wherein the vapouriser includes means for enhancing the phase change from liquid to vapour.

19. An internal combustion engine having an intake manifold and a throttle body in fluid communication with the intake manifold, characterised in that liquid fuel vapourisation apparatus as claimed in any one of the preceding claims, is operatively interposed between the throttle body and the intake manifold.

20. An internal combustion engine according to Claim 19, wherein a separate injector is used for each cylinder or bank of cylinders.

21. Liquid fuel vapourisation apparatus substantially as hereinbefore described with reference to any one of the Figs. 1 to 3.

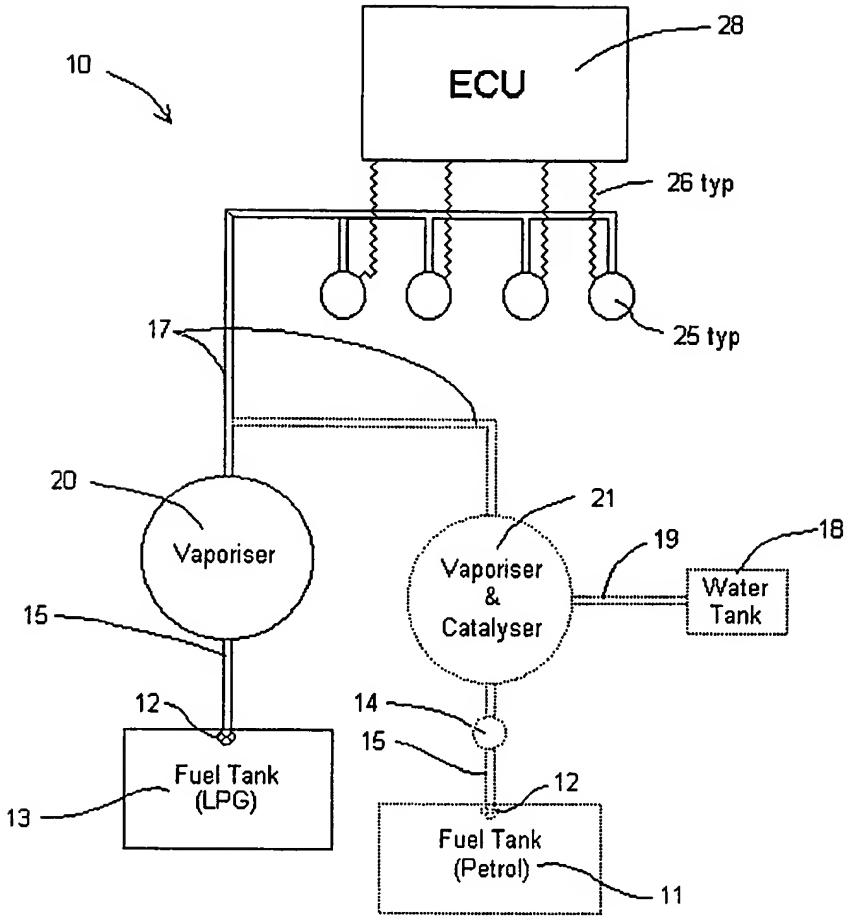
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Fig. 1

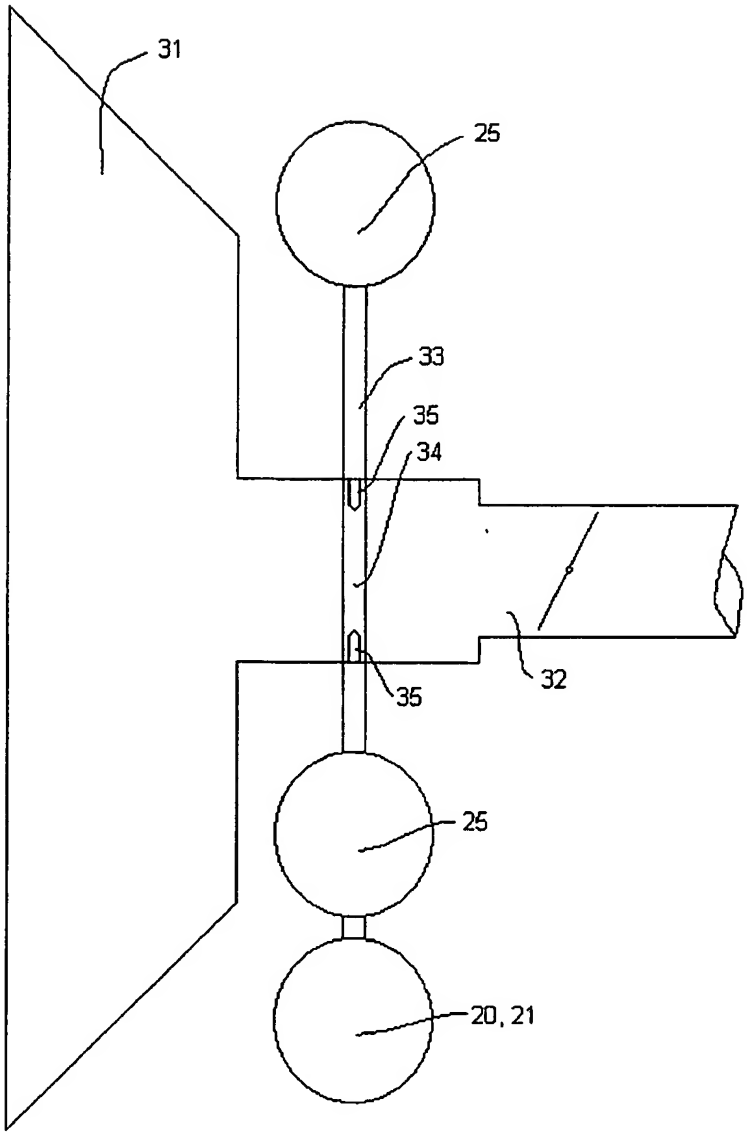

Fig. 2

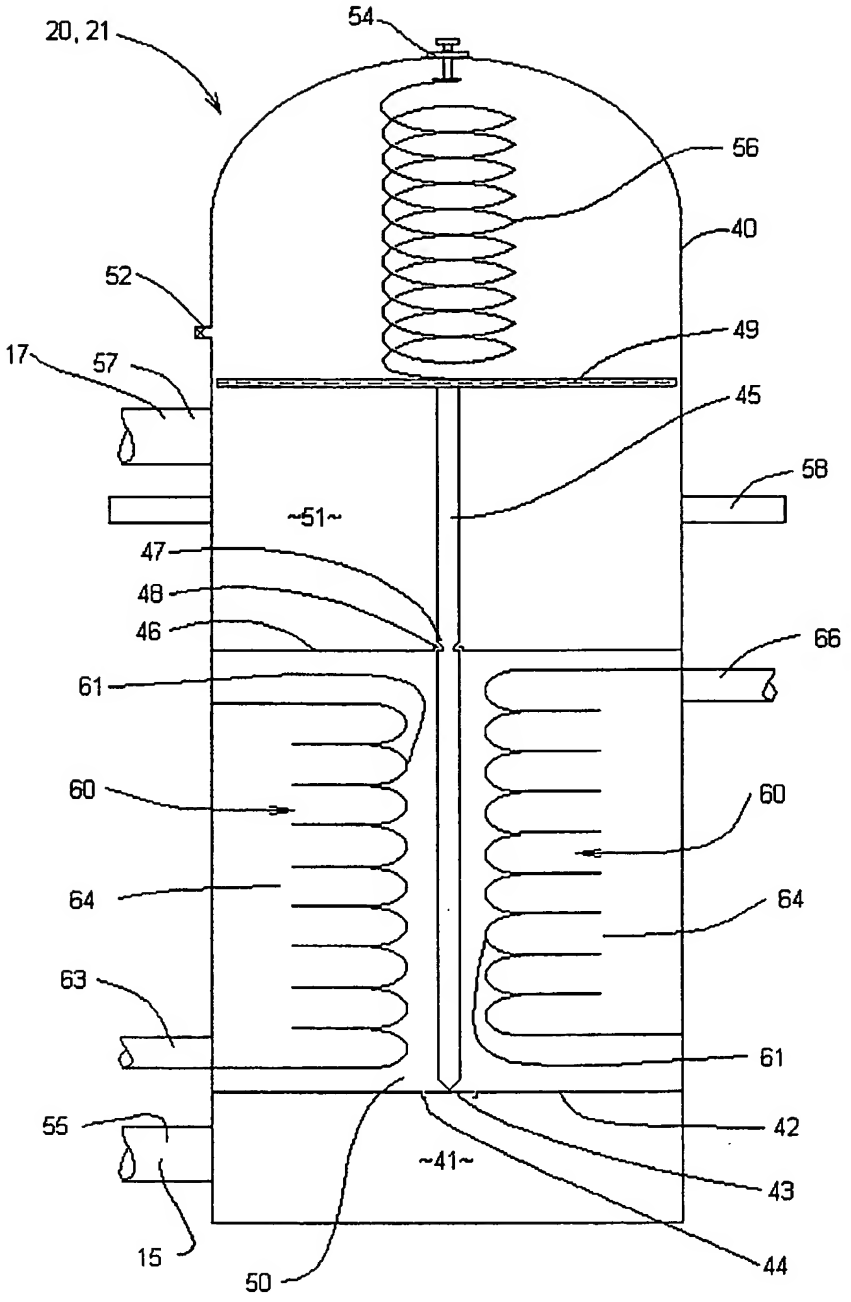
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Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU00/01368

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. [7]: F02M 31/18, 21/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F02M 31/18, 21/06

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU : IPC AS ABOVE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DWPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	AU 28797/97A (SMARTGAS LIMITED) 12 November 1998	
X	See the whole document	1-3, 5-21
Y	See the whole document	4
	GB 2330176A (FORD GLOBAL TECHNOLOGIES INC.)14 April 1999	
Y	See the whole document	4
	GB 2133078A (ORFORD) 18 July 1984	
X	See the whole document	1-3, 5-21

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search
5 January 2001

Date of mailing of the international search report
11 January 2001

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU00/01368

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98/21463A1 (SMARTGAS LIMITED) 22 May 1998 See the whole document	1-3, 5-21
X	AU 34263/95 (BAKER) 2 May 1996 See the whole document	1-3,5-21

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/AU00/01368

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
GB	2330176	EP	1021650	WO	9919618		
GB	2133078	AU	21785/83				
WO	9821463	AU	49348/97				
AU	34263/95	AU	34263/95				
							END OF ANNEX